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REVIEW

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The value of SPECT in the detection of stress injury to the pars interarticularis in patients with low back pain

Katherine Zukotynski^{1,4}, Christine Curtis², Frederick D Grant^{3,4}, Lyle Micheli^{2,4}, S Ted Treves^{3,4*}

Abstract

The medical cost associated with back pain in the United States is considerable and growing. Although the differential diagnosis of back pain is broad, epidemiological studies suggest a correlation between adult and adolescent complaints. Injury of the pars interarticularis is one of the most common identifiable causes of ongoing low back pain in adolescent athletes. It constitutes a spectrum of disease ranging from bone stress to spondylolysis and spondylolisthesis. Bone stress may be the earliest sign of disease. Repetitive bone stress causes bone remodeling and may result in spondylolysis, a non-displaced fracture of the pars interarticularis. A fracture of the pars interarticularis may ultimately become unstable leading to spondylolisthesis. Results in the literature support the use of bone scintigraphy to diagnose bone stress in patients with suspected spondylolysis. Single photon emission computed tomography (SPECT) provides more contrast than planar bone scintigraphy, increases the sensitivity and improves anatomic localization of skeletal lesions without exposing the patient to additional radiation. It also provides an opportunity for better correlation with other imaging modalities, when necessary. As such, the addition of SPECT to standard planar bone scintigraphy can result in a more accurate diagnosis and a better chance for efficient patient care. It is our expectation that by improving our ability to correctly diagnose bone stress in patients with suspected injury of the posterior elements, the long-term cost of managing this condition will be lowered.

Introduction

The economic burden of back pain is estimated to be more than \$90 billion per year in the United States [1,2]. Costs may be due to a variety of factors including primary care, diagnostic imaging, inpatient services, physical therapy and lost work productivity. Recent epidemiological studies suggest a correlation between adult and adolescent complaints [3,4].

The differential diagnosis for back pain is broad and includes degenerative disease, infection, inflammation, tumors and trauma [5-7]. Injury of the pars interarticularis is one of the most common identifiable causes of ongoing low back pain in adolescent athletes [6,8,9]. It constitutes a spectrum of disease from bone stress through spondylolysis and spondylolisthesis. Bone stress may be the earliest sign. It is most common at L5, which is particularly vulnerable to micro-trauma from

repetitive flexion, extension or rotational forces. Repetitive bone stress may result in spondylolysis, a non-displaced fracture of the pars interarticularis. Ultimately spondylolisthesis, or slippage of one vertebral body on another, may occur.

The Diagnosis and Treatment of Spondylolysis

Athletes comprise the majority of patients presenting with spondylolysis [10-12]. Sport specific maneuvers with repetitive twisting rotation and extension increase load on the spine, and may result in stress injury [13,14]. The most frequently presenting complaint is low back pain; either localized or diffuse [8,9,15]. In more severe cases, muscle spasms from difficulty in gait and posture may result.

The medical history should include duration of symptoms, modifying and alleviating factors, level and intensity of sport participation as well as changes in muscle, bowel and bladder function. Physical examination involves inspection and palpation of the spine as well as examination of range of motion [9]. Inspection of the

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spine may reveal hyperlordosis. Palpation for tenderness is useful to identify area(s) of stress, fracture, or slippage [9]. Range of motion is frequently more compromised and painful in extension. The stork test may reveal pain on the contralateral side when standing on one leg. While this test is not specific for pars stress injury, it is highly suggestive of some type of derangement of the posterior elements of the spine [16]. Imaging studies used to evaluate patients with low back pain include: radiographs, bone scintigraphy, computed tomography (CT) and magnetic resonance imaging (MRI).

Radiographs of the spine have limited sensitivity compared with other imaging modalities in detecting bone stress and acute spondylolysis. Furthermore, radiographic defects of the pars interarticularis may not be symptomatic [17,18]. Figure 1 illustrates the radiographic appearance of a long standing pars interarticularis defect.

Bone scintigraphy is very sensitive for the detection of bone stress. Repetitive stress causes local bone remodeling and abnormal uptake of scintigraphic tracer. Single photon emission computed tomography (SPECT) has 10-20 times more contrast than planar bone

scintigraphy and is more sensitive than radiography and planar bone scans. Furthermore, scintigraphic abnormalities have been found to correlate with painful lesions of the pars interarticularis [18-21]. The diagnosis of spondylolisthesis is not made with scintigraphy. Once spondylolisthesis develops, bone stress may be absent at the site of spondylolysis. However, in this case, bone remodeling and tracer uptake may occur at the pars interarticularis immediately above or below the level of fracture. Figure 2 illustrates stress of the pars interarticularis on bone scintigraphy. Figure 3 presents an example where pars stress is identified on SPECT but not on planar bone scintigraphy.

CT demonstrates detailed osseous morphology, is more specific than bone scintigraphy and may predict the probability of ultimate bone healing [22,23]. However, CT of the spine results in higher ionizing radiation exposure compared to bone scintigraphy [24]. Furthermore, there are reports in the literature of a normal spine CT in patients with abnormalities on planar bone scintigraphy and SPECT [16,25]. This may be explained by the fact that tracer uptake in the region of the pars interarticularis on scintigraphic studies corresponds to

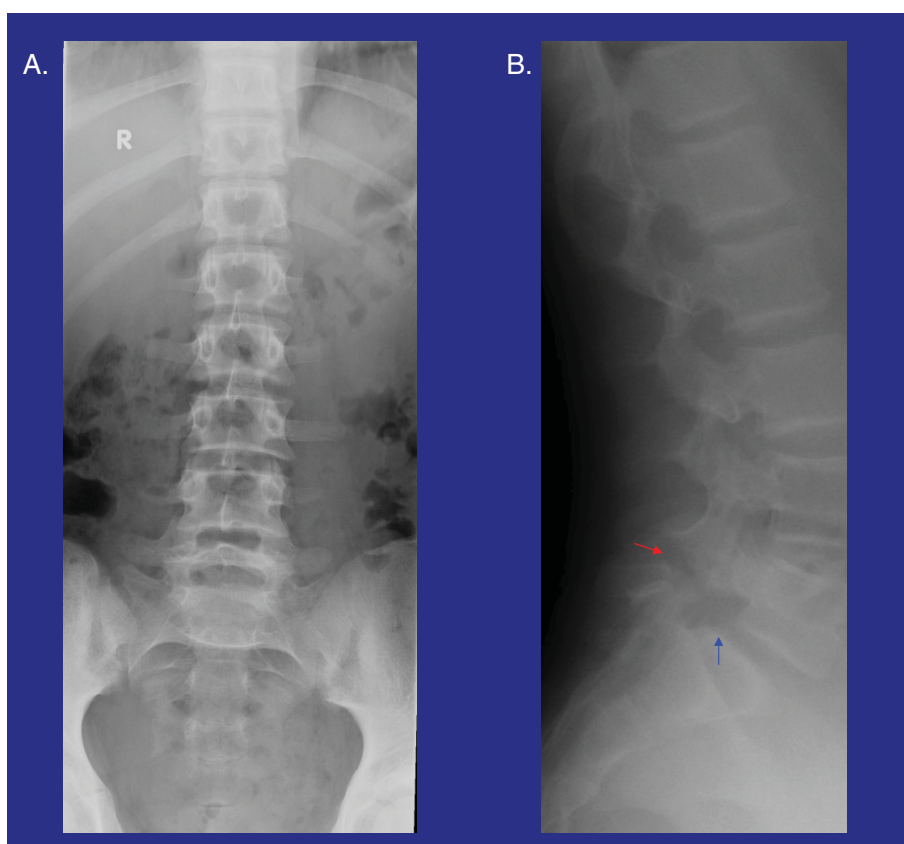


Figure 1 Radiographic findings in a patient with L5 pars interarticularis fracture and mild L5 on S1 spondylolisthesis: AP (A) and lateral (B) images. [Red arrow points to the fracture and blue arrow points to spondylolisthesis of L5 on S1].

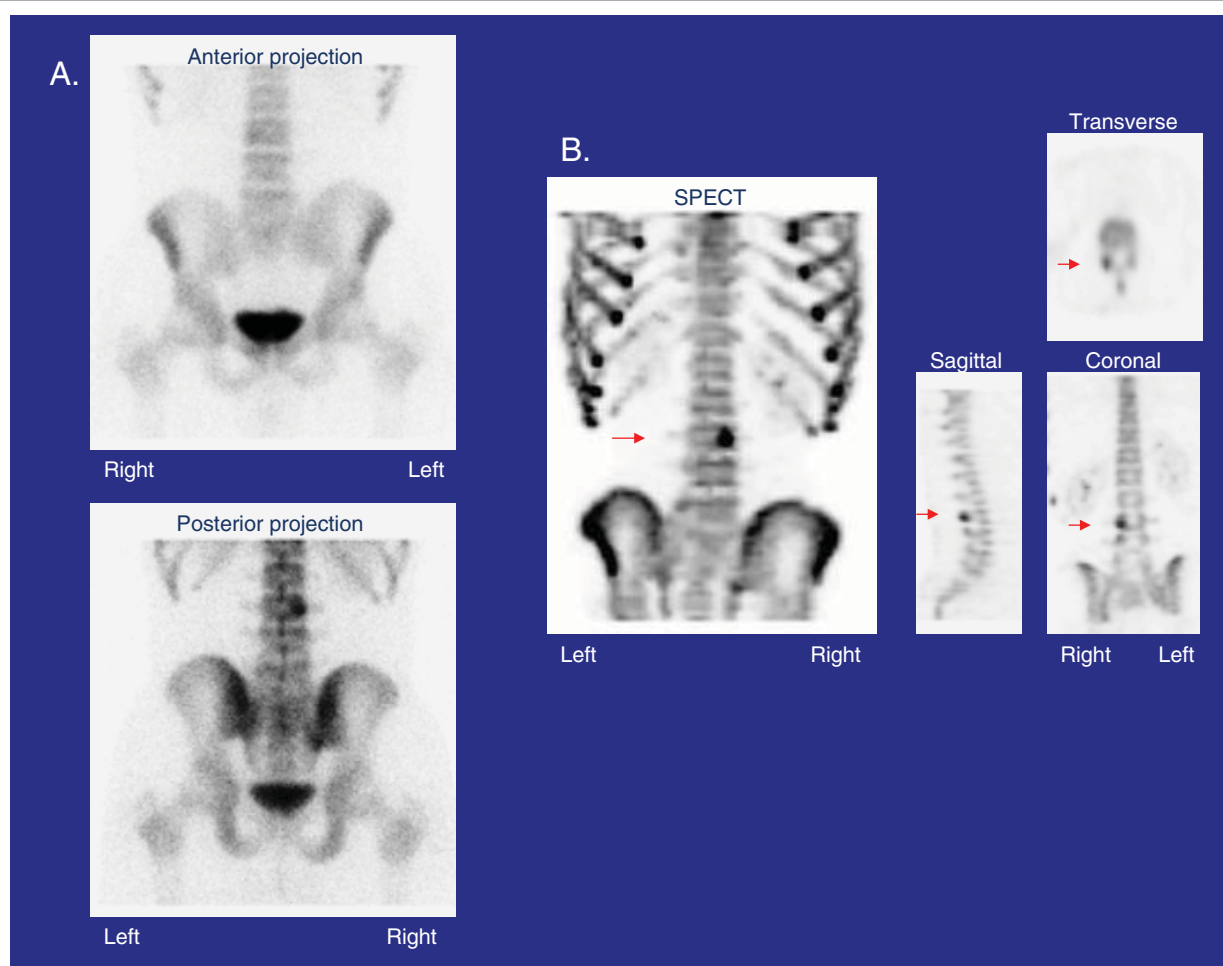


Figure 2 Scintigraphic findings in a patient with right L3 pars stress on planar bone scintigraphy (A) and on SPECT (B). [Red arrows point to the scintigraphic abnormality on SPECT].

bone stress. If this stress has not yet resulted in a fracture, changes may not be visible on CT. The identification of patients with this pattern of scintigraphic findings is particularly important as these patients may have the best chance of healing with early treatment [6]. Figure 4 shows a fracture of the pars interarticularis on CT.

MRI is not as sensitive as SPECT for identifying bone stress of the pars interarticularis and does not delineate bony detail to the same extent as CT [16,25]. MRI is, however, attractive as an imaging modality that does not involve ionizing radiation and that is excellent in identifying alternate pathology including bone edema or abnormalities of the soft tissues, disk and spinal cord.

In general, when bone stress or spondylolysis is suspected, bone scintigraphy with SPECT is recommended. If SPECT demonstrates a pars lesion, a thin-cut CT (1 mm axial sequence) through the area of abnormality on SPECT, is recommended to confirm the diagnosis and

stage the lesion. If SPECT is negative, pars stress is unlikely to be the cause of the low back pain and MRI may be helpful in identifying other causes of back pain [6,26].

Complete bony union offers the best long term prognosis. Some patients attain a fibrous union and are consequently able to return to prior activity, with favorable short-term prognoses. Treatment often includes rest from aggravating activities, non steroidal anti-inflammatory medication, bracing and physical therapy emphasizing hamstring stretching and core strengthening. The length of activity restriction, use of bracing and type of rehabilitation programs varies, reflecting a lack of consensus among practitioners. In recalcitrant cases, electrical stimulation may be added [9,27,28]. Prompt treatment of patients with early pars stress has been shown to result in more predictable symptom relief and less likelihood of progression to spondylolisthesis [29-31]. Surgery is reserved for patients who do not respond to conservative management

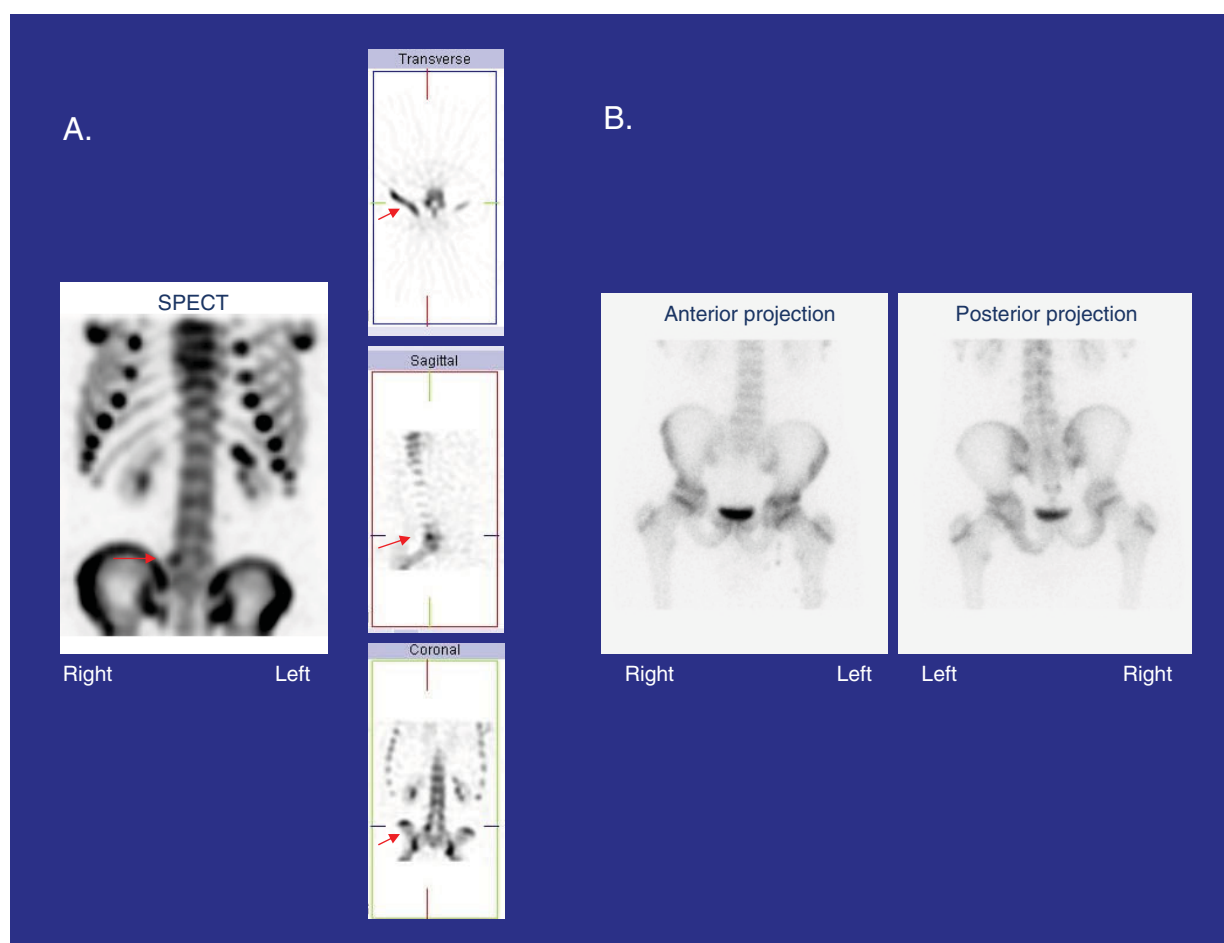


Figure 3 Scintigraphic findings in a patient with right L5 pars stress on SPECT (A), not seen on planar bone scintigraphy (B). [Red arrows point to the scintigraphic abnormality].

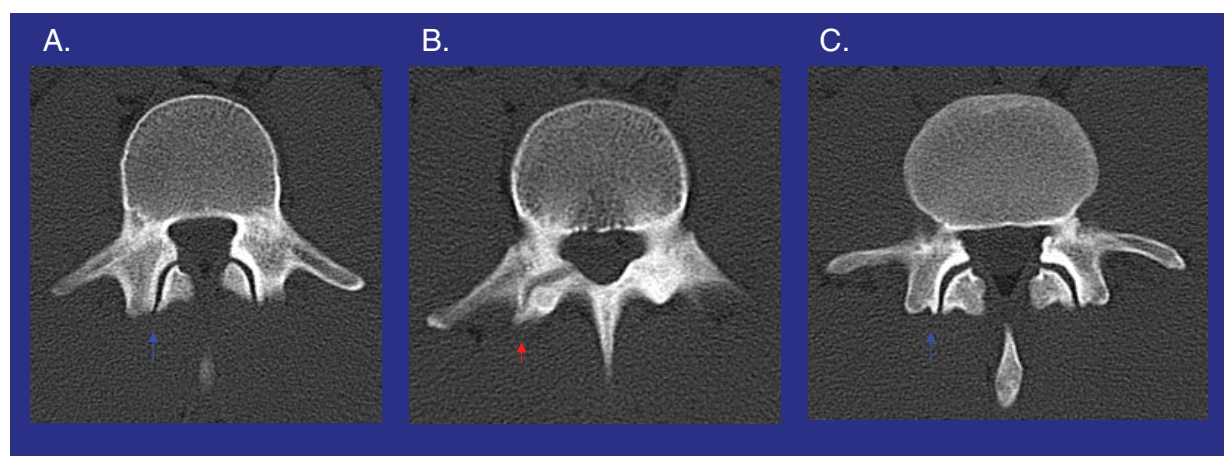


Figure 4 CT findings in a patient with pars interarticularis fracture: Normal facet joint below fracture (A), right L3 pars interarticularis fracture (B), normal facet joint above fracture (C). [red arrow points to the fracture and blue arrows point to normal facet joints].

(approximately 5%), have progressive spondylolisthesis, intractable pain or neurological deficits [18].

The Utility of SPECT over Planar Bone Scintigraphy in the Evaluation of Back Pain

Studies have consistently demonstrated that SPECT is more sensitive than planar bone scintigraphy to identify skeletal lesions [31-33]. Collier et al. compared planar bone scintigraphy and SPECT in 19 adults with radiographic evidence of spondylolysis and/or spondylolisthesis and found that SPECT was more sensitive in identifying sites of "painful" pars interarticularis defects and that SPECT allowed more accurate localization of the defect [19]. In a long-term follow-up study, Bellah et al. reviewed findings on planar and SPECT bone scintigraphy in 162 patients aged 6-32 years with symptoms of low back pain potentially related to stress injury of the pars interarticularis. SPECT showed an abnormal focus of radiotracer uptake in the lumbar spine in 71 patients (44%). All abnormalities detected on planar bone scintigraphy were detected with SPECT. An abnormality was identified in 39 patients (24%) on SPECT alone [20]. Even-Sapir et al. demonstrated SPECT was more sensitive and specific than planar bone scintigraphy in the detection of bone metastasis in a prospective study of 44 patients with prostate cancer [32]. Strobel et al. found that lesion visibility as well as the ability to determine a specific diagnosis was significantly better for SPECT than with planar bone scintigraphy [33].

We conducted an internal review of all patients with low back pain or suspected spondylolysis referred to the Division of Nuclear Medicine at Children's Hospital, Boston for skeletal scintigraphy between October 2005 and September 2006. Of 115 identified patients undergoing skeletal SPECT and planar scintigraphy, SPECT identified an abnormal focus of increased tracer uptake in the pars interarticularis in 42 patients (37%). All abnormalities detected on planar bone scintigraphy were also detected with SPECT. Planar bone scintigraphy identified an abnormal focus of tracer uptake in the pars interarticularis in 19 patients (17%). SPECT identified additional sites of pars stress in 5 of the 19 patients with pars stress suggested on planar bone scintigraphy (26%).

In general, SPECT increases contrast and improves anatomic localization in comparison to planar scintigraphy [34]. In SPECT, images are acquired in multiple projections with the gamma scintillation camera traversing an axial orbit about the patient. Filtered back projection (FBP) or an iterative reconstruction algorithm such as OSEM (ordered subsets expectation maximization) is then used to create a cross-sectional image. The cross-sectional image is a two-dimensional representation of a slice through the patient that would project onto a single dimension on a planar bone scan. In addition, SPECT images may be displayed as a 3D

representation using a volume rendered display to provide better spatial orientation. Maeseneer et al. illustrated how patterns of tracer uptake in the spine on SPECT suggested specific pathology [35]. Degenerative disk disease might show increased tracer uptake centered about the disk space. Pars interarticularis stress might show tracer uptake in the expected location of the pars interarticularis and metastatic disease is more likely to involve the vertebral body with extension to the pedicle [35,36]. Ultimately, SPECT may be fused with CT, if needed, to help add specificity to the findings.

Conclusions

The economic burden of back pain is significant and growing. Epidemiological studies suggest a correlation between adult and adolescent complaints. Pars interarticularis injury, a spectrum of disease ranging from bone stress to spondylolysis and spondylolisthesis, is the most common identifiable cause of ongoing low back pain in adolescent athletes.

In the current era of multi-modality imaging, radiographs, skeletal scintigraphy, CT and MRI all play an important role in imaging patients with back pain. Planar bone scintigraphy has a long history in the diagnosis of patients with suspected injury of the pars interarticularis because it is more sensitive than radiographs for localizing the site of bone stress and because CT of the spine is associated with significant ionizing radiation. The addition of SPECT to planar skeletal scintigraphy increases sensitivity and improves disease localization without exposing the patient to additional radiation. SPECT can also identify early pars stress prior to the development of osseous change detectable with CT. As such, incorporation of SPECT into the standard planar bone scintigraphy routine should lead to a more accurate initial diagnosis. It is our hypothesis that by improving our ability to promptly diagnose patients with suspected injury of the pars interarticularis, the patients will be better served and the long-term cost of management can be lowered.

List of abbreviations used

SPECT: Single photon emission computed tomography; CT: Computed tomography; MRI: Magnetic resonance imaging.

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Authors' contributions

All of the authors have read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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